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EPIDEMIOLOGIC STUDIES

Characteristics and Prognosis of Incomplete Right Bundle Branch Block: An Epidemiologic Study

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A cohort of 1,960 white men aged 40 to 56 years without initial apparent heart disease and with 11 years of annual rest electrocardiograms and 20 year mortality data was followed in the Chicago Western Electric Company Study. Incomplete right bundle branch block was found in 134 men (6.8%) at entry. During follow-up, 222 men developed such block, an incidence rate of 13.6%. Left axis deviation of −30° or less was more frequent in men with than in those without incomplete block at entry (8.2 versus 2.4%). Men with left axis deviation also had a higher incidence of incomplete right bundle branch block. Similarly, men developing incomplete block had a significantly greater risk of developing left axis deviation. The associations between incomplete block and left axis deviation were unrelated to age and body weight.

Men with incomplete block had a significantly greater likelihood of developing complete right bundle branch block. The 11 year incidence rate of complete block was 5.1% for men with baseline incomplete block and 0.7% for those without. Complete block developed in 2 of 220 incident cases of incomplete block but in none of the 440 control men matched by age and duration of follow-up. Although incomplete right bundle branch block was not related to an increased risk of death in 20 years from coronary heart disease and cardiovascular diseases, the study data suggest that such block is frequently a manifestation of primary abnormality of the cardiac conduction system in middle-aged men.

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Many cardiologists (1,2) have concluded that incomplete right bundle branch block on the electrocardiogram does not represent impairment in the right conduction system. It has been suggested (3) that in children and young adults without overt heart disease incomplete bundle branch block may have no prognostic significance. On the other hand, little information is available on its significance in middle-aged and elderly people, especially when it is a new development.

This prospective epidemiologic study describes the characteristics and long-term prognosis of men with such block but without initial apparent heart disease. It also presents data on whether this is really a conduction disturbance.

Methods

Study group. The data are from the Chicago Western Electric Company Study, a long-term prospective investigation of coronary heart disease initiated in 1957. Details of the selection and characteristics of this cohort have been reported (4). A group of 2,107 middle-aged men employed by the Hawthorne Works of the Western Electric Company underwent an extensive baseline examination, including a 12 lead electrocardiogram at rest. For available survivors of the cohort, examinations (including electrocardiograms) were repeated annually for 11 consecutive years.

This study is concerned with only white men aged 40 to 56 years (2,056 of 2,107 men). To avoid potential confounding of data, this study excluded 96 men: those with rheumatic or congenital heart disease or a history of coronary heart disease at baseline (45 men) and those with any of the following electrocardiographic changes: Q-QS wave ab-

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normalities (Minnesota Code 1) (26 men); complete atrioventricular (AV) block (Code 6-1) (1 man); major ventricular conduction defect other than incomplete right bundle branch block (20 men), that is, complete left or right bundle branch block (Code 7-1 or 7-2-1), anterior fascicular block (Code 7-7) or bifascicular block (Code 7-8); atrial fibrillation (Minnesota Code 8-3-1) (3 men); and supraventricular rhythm (Minnesota Code 8-4-1) (1 man). For the remaining 1,960 men, follow-up as to vital status was available for 20 years after entry.

Minnesota Code reading of electrocardiograms and quality control review. All electrocardiograms were read by Minnesota Code (5) at the University of Minnesota reading center. Those with incomplete right bundle branch block plus a randomly selected 10% sample of those without such block were reexamined to assure accuracy of diagnosis. Disagreements between the two examinations were resolved by consensus of two Minneosota Code reading center specialists (R. Prineas and M. McDonald) and a cardiologist (Y. Liao). No false negative cases were found in the randomly selected sample of 160 men who had no abnormal conduction. Diagnostic correction from original incident cases of incomplete block to prevalent cases were made for four men.

Definitions. Requirements for the diagnosis of incomplete right bundle branch block were: a QRS duration of less than 0.12 second in each of leads I, II, III, aVL and aVF, and an R′ or r′ wave in either lead V_1 or V_2 (Minnesota Codes 7-3, 7-5). Complete right bundle branch block was defined as a QRS duration of 0.12 second or greater in a majority of beats (of the same QRS pattern) in any of leads I, II, III, aVL or aVF, plus R′ greater than R in lead V_1 or V_2; or a mainly upright QRS complex plus a peak R wave duration of 0.06 second or greater in lead V_1 or V_2; or an S wave duration greater than the R wave duration in all beats in lead I or II (Minnesota Code 7-2-1).

Causes of death were classified by reviewing death certificates, and were coded according to the Eighth Revision of the International Classification of Diseases (6). The coding was done independently in duplicate without knowledge of baseline characteristics. Disagreements between duplicate codes were investigated and resolved.

Control group. Prevalent cases of incomplete right bundle branch block were compared with the men free of such change at entry. Incident cases of incomplete block were matched by age and duration of electrocardiographic follow-up with two randomly selected control men who never manifested such block.

Statistical methods. The *t* test was used to compare two sample means for those with and without incomplete block. To account for varying lengths of follow-up, life table analyses were used to estimate cumulative incidence rates of incomplete and complete right bundle branch block, left axis deviation and long-term mortality rate from coronary heart disease, major cardiovascular diseases and all causes. Survival experiences for men with and without incomplete block were compared using the Lee-Desu statistic (7).

Results

Prevalence and incidence of incomplete right bundle branch block. Examples of incomplete right bundle branch block are illustrated in Figure 1.Besides the rsR′ or rsr′ characteristic configuration in lead V_1 or V_2, the terminal vector in the vast majority of cases of block was oriented rightward and inferiorly or superiorly. Of the 1,960 men at entry, 134 (6.8%) showed evidence of incomplete block. For the age groups 40 to 44 (n = 598), 45 to 50 (n = 760) and 51 to 56 (n = 602), the prevalence rate was 6.5, 6.7 and 7.3%, respectively.

During the follow-up years, 222 men developed incomplete right bundle branch block. Approximately one half of the cases (113 men) were detected in the first 4 years. With use of the life table method (1 year intervals), the 11 year cumulative incidence rate of such block was 13.6%. For the age groups 40 to 44 (n = 559), 45 to 50 (n = 709) and 51 to 56 (n = 558), the 11 year incidence rate was 13.4, 14.7 and 13.0%, respectively. Neither prevalence nor incidence rates of incomplete right bundle branch block differed significantly by age group.

Incomplete right bundle branch block and left axis deviation. Table 1 shows that among men with incomplete block at baseline, compared with those without this finding, a greater proportion had left axis deviation of 0° or less (17.3% versus 12.5%; p = NS). For more severe left axis deviation (−30° or less), the proportions were 8.2 versus 2.4% ($p < 0.001$). The proportions with axis deviation in

Figure 1. Serial electrocardiograms of a 54 year old man showing progression from normal conduction to incomplete right bundle branch block (IRBBB), and from incomplete right bundle branch block to complete right bundle branch block (CRBBB).

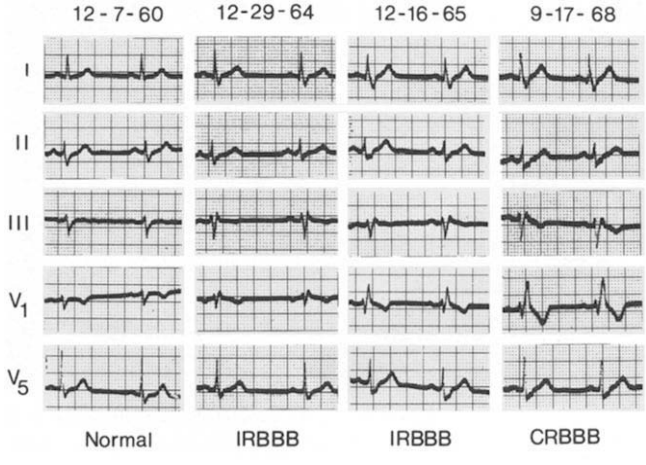

Table 1. Prevalence Rates of Left Axis Deviation in Men With and Without Incomplete Right Bundle Branch Block at Baseline

		Axis Deviation					
		Axis ≤ 0°			Axis ≤ −30°		
			Rate (%)			Rate (%)	
	No. of Men	n	Crude	Age Adjustment	n	Crude	Age Adjustment
IRBBB	134	23	17.3	17 3	11	8.2	8.2
No IRBBB	1,825	227	12.5	12.4	44	2.4	2.4
p Value*			0.114	0.101		<0.001	<0.001

*Incomplete right bundle branch block (IRBBB) versus no such block.

the two groups did not change after adjustment for age differences between the groups.

Baseline left axis deviation was associated with an increased likelihood of developing incomplete right bundle branch block (Table 2). With life table analyses, the 11 year cumulative incidence rate of such block was significantly greater in men with a baseline axis of 0° or less than in those with an axis greater than 0° (20.0 versus 12.8%). After age adjustment, the difference remained statistically significant ($p = 0.016$). For men with a baseline axis of −30° or less, the incidence rate of incomplete block was even greater (26.2%). This was twice the rate in men with an axis greater than −30° (13.4%), but the difference was not statistically significant at the $p = 0.05$ level, presumably because of the small number of men with an axis of −30° or less.

Furthermore, those with incomplete right bundle branch block at either baseline or follow-up examination had a greater likelihood of developing left axis deviation, especially an axis of −30° or less. Table 3 shows the 11 year cumulative incidence rates of left axis deviation in prevalent cases of incomplete right bundle branch block versus men without such block, both of whom were free of left axis deviation at baseline. For either an axis of 0° or less or an axis of −30° or less, prevalent cases of incomplete block had a greater incidence of left axis deviation than did men without block, but the difference did not reach statistical significance for an axis of 0° or less. In men with incomplete block the incidence of an axis of −30° or less was almost twice that of men without such block (20.5 versus 10.6%), a significant difference without and with age adjustment.

Among the 222 incident cases of incomplete right bundle branch block, 166 and 206 men, respectively, did not have an axis of 0° or less or an axis of −30° or less before the first detection of incomplete block. The incidence rates of an axis of 0° or less and of an axis of −30° or less, either coincident with or subsequent to such block, were compared between the cases and two comparison men matched by age and duration of follow-up; these individuals never had incomplete right bundle branch block and did not have left axis deviation (axis 0° or less and −30° or less, respectively) before being matched (Table 4). The 5 and 10 year cumulative incidence rates of an axis of 0° or less were greater in the men with incomplete block than in the control men (15.1 versus 11.1% and 24.1 versus 20.8%, respectively). These differences were not significant, however. Incidence rates of an axis of −30° or less were significantly different for those with incomplete block and control men at both 5 (9.6 versus 2.8%) and 10 years (20.7 versus 7.0%).

To examine the relation to left axis deviation of factors

Table 2. Eleven Year Cumulative Incidence Rates of Incomplete Right Bundle Branch Block by Left Axis Deviation at Baseline: Life Table Analysis

		Incidence of IRBBB				
			Rate (%)			
LAD	No. of Men	n	Crude	p Value	Age-Adjusted	p Value
≤ 0°	227	36	20 0	0.025	21.1	0.016
> 0°	1,598	186	12.8		13.0	
≤ −30°	44	8	26 2	0.308	*	
> −30°	1,781	205	13.4			

*The number of incident cases of incomplete right bundle branch block (IRBBB) for left axis deviation (LAD) at −30° or less was too small for age adjustment.

Table 3. Eleven Year Cumulative Incidence Rates of Left Axis Deviation in Men With and Without Incomplete Right Bundle Branch Block at Baseline: Life Table Analysis

	No of Men	n	Rate (%) Crude	p Value	Age-Adjusted	p Value
Incidence of LAD ≤0°						
IRBBB*	111	28	28 8	0.158	28 6	0 180
No IRBBB*	1,599	304	22 0		22 3	
Incidence of LAD ≤ −30°						
IRBBB†	123	21	20 5	0.016	21 7	0 008
No IRBBB†	1,782	156	10 6		10.9	

*Men without an axis of 0° or less at baseline; †men without an axis of −30° or less at baseline Abbreviations as in Tables 1 and 2.

other than age, tests were done to assess whether men with incomplete right bundle branch block had greater body weight and body mass index, which can lead to a more leftward shift of axis. Both prevalent and incident cases of incomplete block had similar height but a lower (not higher) body weight and body mass index compared with men without such block (Table 5). This difference was present for both nonsmokers and smokers, and was significant in two of the four comparisons and of borderline significance in the other two.

The proportion of cigarette smokers at baseline was greater in cases of incomplete block than in men without such block; the difference was statistically significant only for the prevalent cases (Table 5). For smokers, the number of ciagarettes smoked per day was similar for those with and without incomplete right bundle branch block. No association was found between such other baseline traits as serum cholesterol, alcohol comsumption and blood pressure and bundle branch block.

Risk of development of complete right bundle branch block. Complete right bundle branch block was found in 17 men during 11 years of follow-up of the cohort. Table 6 gives the cumulative incidence rates of complete right bundle branch block for those with and those without incomplete block at baseline (life table analysis). Prevalent cases of incomplete block had seven times the 11 year incidence rate of complete right bundle branch block compared with those without. Of the 222 men who developed incomplete right bundle branch block during the study, 2 had complete right bundle branch block before the first detection of incomplete block; they were not counted as cases of complete block in the incident incomplete right bundle branch block group. For the remaining 220 cases of incomplete block, 2 developed complete right bundle branch block. But of the 440 age-matched and follow-up duration-matched individuals who never manifested such block (2:1 matching), none had complete block during follow-up.

Table 4. Cumulative Incidence Rates of Left Axis Deviation in Incident Cases of Incomplete Right Bundle Branch Block and Control Men: Life Table Analysis

	No. of Men	5 Year Incidence of LAD n	Rate (%)	p Value	10 Year Incidence of LAD n	Rate (%)	p Value
≤0°							
Incident IRBBB*	166	19	15 1	0.284	26	24.1	0.535
Control men*	332	31	11 1		44	20.8	
≤ −30°							
Incident IRBBB†	206	15	9 6	<0.001	24	20.7	0.002
Control men†	412	9	2.8		16	7.0	

*Incident cases of incomplete right bundle branch block (IRBBB) without an axis of 0° or less before first detection of such block. Control men were 2 for 1 age-matched and follow-up duration-matched individuals who never manifested incomplete right bundle branch block and who did not have an axis of 0° or less before being matched; †incident cases of incomplete right bundle branch block without an axis of −30° or less before the first detection of such block Control men were 2 for 1 age-matched and follow-up duration-matched individuals who never manifested incomplete right bundle branch block and who did not have an axis of −30° or less before being matched. LAD = left axis deviation

Table 5. Mean (SD) of Height, Weight, Body Mass Index and Cigarette Smoking for Men With and Without Incomplete Right Bundle Branch Block

	Prevalent IRBBB (N = 134)	Control Men* (N = 1,826)	p Value	Incident IRBBB (N = 222)	Control Men† (N = 444)	p Value
Height (cm)	175.3 (6.6)	174.5 (6.4)	0.12	175 3 (6.4)	175.0 (6.4)	0.58
Weight (kg)	74.1 (11.0)	77.3 (10.9)	<0.01	76.1 (11.0)	78.2 (10.5)	<0.05
BMI (kg/m^2)						
Nonsmokers	24.9 (4.0) (n = 44)	26.1 (3.2) (n = 816)	0.06	25.4 (3.0) (n = 90)	26.3 (3.2) (n = 199)	<0 05
Smokers	24.0 (2.9) (n = 90)	25.1 (3.2) (n = 1,010)	<0.01	24.7 (3.4) (n = 132)	25.3 (3.0) (n = 245)	0.09
All	24.3 (3.3)	25.6 (3.2)	<0.01	25.0 (3.3)	25.7 (3 1)	<0.01
Smoking (%)	67.2	55.3	<0.01	59.5	55.2	0.29
Cigarettes per day	18.5 (7.5)	18.5 (9.0)	0.99	19.2 (10.3)	18.7 (9.2)	0.63

*Men without incomplete right bundle branch block (IRBBB) at baseline; †2 for 1 age-matched and follow-up duration-matched individuals who never manifested incomplete right bundle branch block. BMI = body mass index.

Long-term risk of death from coronary heart disease, cardiovascular disease and all causes. Table 7 indicates that men with incomplete right bundle branch block at baseline had 20 year cumulative age-adjusted rates of death due to coronary heart disease and cardiovascular diseases similar to those of men without such block. Although men with incomplete block had a higher death rate from all causes, the difference was not statistically significant (p = 0.66). The 15 year cumulative mortality rate after first detection of incident incomplete right bundle branch block was also compared with that for age-matched and follow-up duration-matched individuals who never manifested such block. The results were similar. Incident cases of incomplete block also had a nonsignificantly greater mortality rate from all causes of death than did control men (p = 0.119).

In comparisons of survival experiences for the three causes of death between the men with incomplete right bundle branch block (prevalent and incident cases, respectively) and control men by Lee-Desu statistics, none of the six pairs of comparison showed significant differences (p = 0.286 to 0.680).

Discussion

The nature of incomplete right bundle branch block. Judgments vary as to the nature and meaning of incomplete right bundle branch block, a common electrocardiographic finding in both hospital- and community-based studies. Some experts believe that it does not represent impairment in the conduction system. In studies of dogs, Moore et al. (1) reported so-called incomplete right bundle branch block that was caused by heritable focal hypertrophy of the right ventricle, not by delay in conduction in the right bundle branch. This electrocardiographic pattern also was

Table 6. Cumulative Incidence Rates of Complete Right Bundle Branch Block in Men With Incomplete Right Bundle Branch Block and Control Men: Life Table Analysis

	No. of Men	n	Rate (%)	p Value
Eleven Year Incidence of CRBBB				
Prevalent IRBBB	134	6	5 14	0.036
No IRBBB	1826	11	0.74	
Six Year Incidence of CRBBB*				
Incident IRBBB†	220	2	1 34	—
Control men‡	440	0	0.00	

*Six years was the average follow-up duration after the first detection of incident incomplete right bundle branch block (IRBBB); †incident cases of incomplete right bundle branch block were those who had no complete right bundle branch block (CRBBB) before the first detection of incomplete block; ‡control men were 2 for 1 age-matched and follow-up duration-matched individuals who never manifested incomplete right bundle branch block.

Table 7. Cumulative Mortality Rates in Men With Incomplete Right Bundle Branch Block and Control Men: Life Table Analysis

	No. of Men	CHD		CVD		All Causes	
		n	Rate (%)	n	Rate (%)	n	Rate (%)
Twenty Year Age-Adjusted Mortality							
Prevalent IRBBB	134	17	13.6	22	17.2	37	27 3
No IRBBB	1,824	211	12.5	264	15 4	443	24.3
Fifteen Year Cumulative Mortality							
Incident IRBBB	222	16	9.0	21	11.9	45	23 0
Control men*	444	40	10.0	47	11.7	71	17.3

*The 2 for 1 age-matched and follow-up duration-matched individuals who never manifested incomplete right bundle branch block (IRBBB). CHD = coronary heart disease; CVD = cardiovascular diseases

observed in other conditions, including cardiac displacement from alterations in chest configuration (8) and congenital or acquired heart disease with right ventricular dilation or hypertrophy (9,10). Another common cause for an incomplete right bundle branch block pattern has been technical error in routine recording of electrocardiograms (11,12).

In contrast, other studies provide evidence of the validity of the existence of incomplete right bundle branch block as an abnormality of cardiac conduction. Animal experiments have shown that injuries of the right bundle branch may cause this pattern and that there can be an intermediate phase between incomplete and complete block (13–15). The same findings have also been demonstrated in humans during both open heart surgery (16) and cardiac catheterization (17).

The present study presents longitudinal data on incomplete right bundle branch block in a cohort of working white men aged 40 to 56 years old at entry. Several findings about the characteristics and prognosis of this abnormality that have not previously received much attention support the concept that incomplete right bundle branch block often represents an impairment in conduction, as indicated in this study.

Associations between incomplete right bundle branch block and left axis deviation. Few of the previous studies commented on the relation between left axis deviation and right bundle branch disturbances. Most of those (18,19) focused only on complete block and not on incomplete block. The present study found that left axis deviation was associated with an increased likelihood of having and of developing incomplete right bundle branch block. At the same time, both prevalent and incident cases of such block had a significantly greater likelihood of developing an axis of $-30°$ or less.

The significance of left axis deviation in humans has been extensively evaluated. Grant (20) and subsequently other investigators (21–24), studying electrocardiographic and pathologic correlations, showed that patients with left axis deviation (axis $-30°$ or less) had a higher prevalence rate of myocardial fibrosis or infarction involving the anterior division of the left bundle branch. In a clinical study of 100 consecutive cases with left axis deviation, Grayzel and Neyshaboori (25) observed that some individuals with an axis between 0 and $-30°$ represent examples of mild slowing or delay of conduction within the left anterosuperior fascicle. With exercise testing, Miller et al. (26) found that asymptomatic persons with an isolated axis equal to or greater than $-30°$ had significantly more ischemic ST segment changes and premature ventricular complexes than did an age-matched control group.

The prognostic significance of left axis deviation also has been sought in population studies. Yano et al. (27) reported that men with QRS axes of $-30°$ to $-44°$ and $-45°$ to $-90°$ had a higher incidence of coronary heart disease than did control normal men during observation periods of 3 to 6 years, but the differences were not statistically significant, possibly because of the small number of event cases. Nevertheless, other prospective studies (28,29) did find that men with left axis deviation less than or equal to $-30°$ had a greater incidence of nonfatal or fatal cardiovascular events than did a control group.

Although aging itself is associated with a leftward shift of the QRS axis (30), the high prevalence and incidence of an axis of $-30°$ or less in persons with incomplete right bundle branch block in the present study cannot be explained by advanced age. With use of both age-adjusted comparisons and an age-matched control group, left axis deviation was still seen significantly more often in those with incomplete block.

A positive relation between body weight and left axis deviation has been found by several authors (32,33). In our study, however, men with incomplete block weighed less than those without. Overweight therefore did not account for the increased prevalence and incidence of left axis deviation in men with such abnormal conduction. Men with incompete block were more often smokers at baseline than were those without. Smoking may cause damage to the

JACC Vol 7, No 3
March 1986 492–9

conduction system. However, no significant relation was found between baseline smoking status and incidence of incomplete block.

Role of coronary artery disease. It is unlikely that a confounding variable or a technical error of measurement was responsible for the association of incomplete right bundle branch block and axis deviation. The process accounting for these relations in this cohort is not known. It is possible that a single lesion or factor concomitantly or sequentially influences the right bundle branch and the anterior division of the left bundle branch because of their close anatomic relation and vulnerability. The right bundle branch and the anterior division of the left bundle are both normally nourished by the perforating branches of the anterior descending coronary artery. Coronary heart disease, especially with some obstruction of this artery, with or without anteroseptal or anterolateral myocardial infarction, could easily result in disturbances of these two bundle branches (34). Grant (20) found that R′ deflections in the precordial leads with left axis deviation but normal QRS duration, defined as incomplete bundle branch block in the present study, were associated at autopsy, in most cases, with myocardial infarction. Autopsy studies are inevitably biased toward lethal disease such as myocardial infarction, but the study does provide some evidence that a sclerotic process of the coronary arteries may play an etiologic role in the association between incomplete right bundle branch block and left axis deviation.

Role of degenerative fibrotic process. A degenerative process in or near the area of the conduction system is also an etiologic possibility. Careful pathologic studies of the conduction system by Lev (35), Lenegre (36) and Davies and Harris (37) have revealed that in persons over age 40, isolated involvement of the conduction system by a degenerative fibrotic process, without significant involvement of the myocardium or other cardiovascular disease, is an important factor leading to bilateral bundle branch conduction defects.

Risk of developing complete right bundle branch block. In the Western Electric Company cohort, both prevalent and incident cases of incomplete right bundle branch block had a greater likelihood of developing complete right bundle branch block. Compared with prevalent cases of incomplete block, incident cases seemed to have a lower incidence rate of complete block. This may be due to the shorter period of follow-up and the complexities of dealing with this in the analysis. The average years of follow-up for incidence of complete block in prevalent cases of incomplete block and men without this conduction abnormality were 9.2 and 9.3 years, respectively. For incident cases of incomplete block the average follow-up period was 5.7 years after the first detection of the abnormality. Among the 17 incident cases of complete right bundle branch block, in more than half (10 cases) the abnormality developed after the sixth follow-up year. Short follow-up time may lead to underestimation of risk despite use of life table analyses to account for varying follow-up periods. Our finding was similar to that of the only previous report by Rabkin et al. (38) from the Manitoba Study. They also found that men with incomplete right bundle branch block (combined prevalent and incident cases) had a significantly greater incidence of complete right bundle branch block than did the entire cohort during nearly 30 years of follow-up.

Clinical observations have demonstrated that there is a form of electrocardiographically manifested conduction abnormality intermediate between normal conduction and complete right bundle branch block (12,39). Serial observation of electrocardiographic change over time in men in our study demonstrated changes in QRS duration and configuration in lead V_1 indicative of an increase in degree of right bundle branch block (Fig. 1). These findings on transition through the intermediate stage to complete block support the inference that in many cases incomplete right bundle branch block is indeed an abnormality in conduction.

Implications. Although long-term rates of death due to coronary heart disease, cardiovascular diseases and all causes for men with incomplete right bundle branch block were not statistically significantly greater than for those without, this does not necessarily imply that in the majority of cases such block does not represent impaired conduction. Two findings relevant to this matter were noted in this prospective epidemiologic study. First, the close association between incomplete right bundle branch block and left axis deviation suggests a possible common pathophysiologic basis for the two electrocardiographic changes. Second, a greater risk of developing complete right bundle branch block in those with incomplete block indicates that the latter may be an intermediate form between normal conduction and complete right bundle branch block. The present data suggest that incomplete right bundle branch block frequently is a manifestation of an abnormality of the conduction system in middle-aged men without other overt heart disease.

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